ATMS Pre-Launch Testing and Performance Assessment

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Overview

- **Proposed additional ATMS pre-launch testing**
  - Antenna pattern (FU2, more cuts and beam positions)
  - Radiometric (FU2, better characterization of non-linearity)
  - Integrated sidelobe test (EDU, better characterization of scan bias)
- **Generation of ATMS proxy data using AMSU observations**
  - TDR/SDR data derived from AMSU Level 1B and models for surface polarization, transmittance, and atmospheric horizontal correlation (for extreme scan angles not measured by AMSU)
  - ATMS RDR data derived from ATMS TDR
- **Development of improved ATMS/CrIMSS SDR/EDR error models**
  - Allows for influence of scene (lat/lon, season, scan angle, surface type, etc.)
  - Simple, non-linear modeling structure (based on neural network retrieval trained using CrIMSS proxy data derived from IASI/AMSU)

ATMS Pre-Launch Testing

- Essential for two objectives:
  - Ensure sensor meets performance specifications
  - Ensure calibration parameters that are needed for SDR processing are adequately and accurately defined
- PFM testing revealed several issues that will require calibration corrections in the SDR:
  - Non-linearity (temperature-dependent for 31.4-GHz channel)
  - Cross-polarization (sometimes 10X higher than AMSU)
  - Antenna beam spillover from secondary parabolic reflector approaching 2% for some channels
- EDR specifications may still be met (evaluation in progress) if pre-launch corrections are “valid” on-orbit
- On-orbit spacecraft maneuvers for NPP could provide improved calibration parameters to correct any scan bias

The Case for Additional ATMS Testing

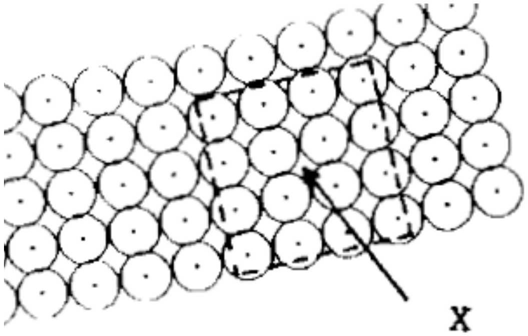
- It may be possible to include additional tests in FU2 development plan, provided marginal cost and schedule impacts are very low

- Recent discussions with NGES/NGST have explored the feasibility of the following additional testing for FU2:
  - Antenna pattern testing (more cuts, more beam positions, better characterization of cross-polarization)
  - Radiometric testing in thermal vacuum to assess repeatability/uncertainty of nonlinearity correction
  - Integrated Sidelobe Test (IST) using LN_2-cooled calibration target (EDU presents least number of logistical hurdles)

SDR Algorithm Corrections

- **Cold Space Bias Correction (CSBC)**
  - Earth and spacecraft contamination of sidelobes (ΔT_{SL})
  - Correction to Rayleigh-Jeans approximation (ΔT_{RJ})
  - $T_C = (2.726 + \Delta T_{RJ}) + \Delta T_{SL}$
- **Scan Bias Correction (SBC)**
  - 1st order correction
  - $T_B = C_0 + C_1 T_A$; T_B is the scan-bias corrected brightness temp.
- **Resampling (Backus-Gilbert)**

$$\tilde{T}_A(\vec{\rho}_d) = \sum_{i=1}^{N} a_i T_A(\vec{\rho}_i)$$



- **Non-Linearity Correction (NLC)**
  - **$T = T_{LIN} + T_{NL}$; T_{LIN} is the linear brightness temp. estimate and T_{NL} is the NLC times a scaling factor**
  - **T_{NL} is a function of channel and RF shelf temperature**

Ronson Chu, "ATMS SDR Radiometric Calibration ATBD," 12 Mar. 07

Gene A. Poe, "Optimum Interpolation of Imaging Microwave Radiometer Data," TGARS, Vol. 28, No. 5, Sept. 1990

Implications if Additional Testing is Not Performed

- Experience with AMSU scan-dependent biases on Aqua indicates a degradation of AIRS/AMSU temperature profile retrieval skill approaching 0.5K in problematic areas.

- EDR performance would be compromised when high-contrast thermal signatures are present in window channel observations:
  - Sounding near coastlines, hurricane eyewalls, and rainbands, where there are high thermal contrasts
  - Water vapor and cloud sensing over ocean

- Data assimilators will also be affected.

- The absolute accuracy of surface sensitive channels will be degraded by polarization impurities if a correction is not implemented. ATMS pattern measurements suggest that four pattern cuts are necessary to derive a reliable correction.

SDR Error Due to Polarization Impurity

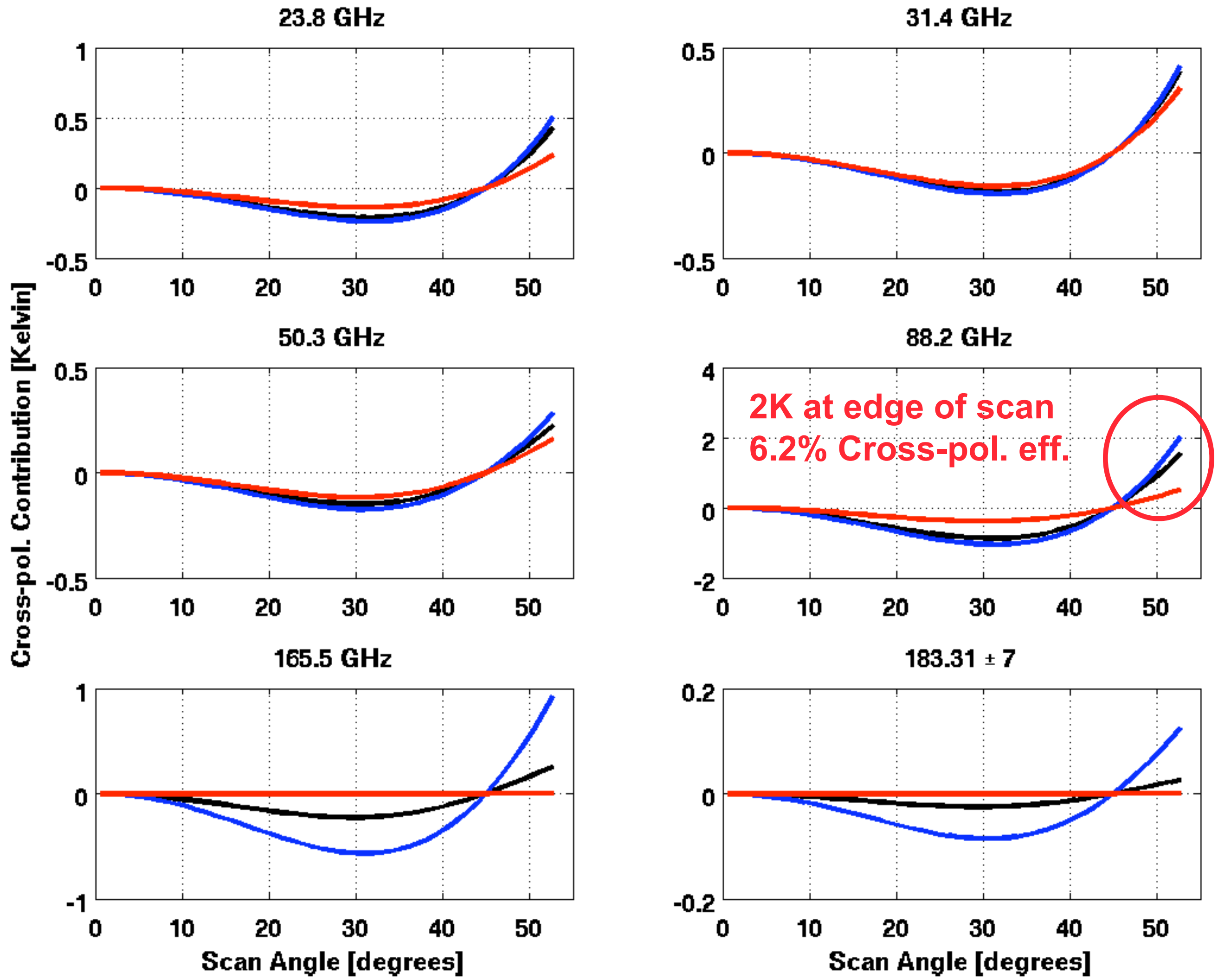
Red: July 25° Lat. FL (summer)

Black: Standard Atmos. 1976

Blue: Mar. 46° Lat. WI (winter)

Ocean surface (fastem2)

Cross-pol efficiencies at beam position 48



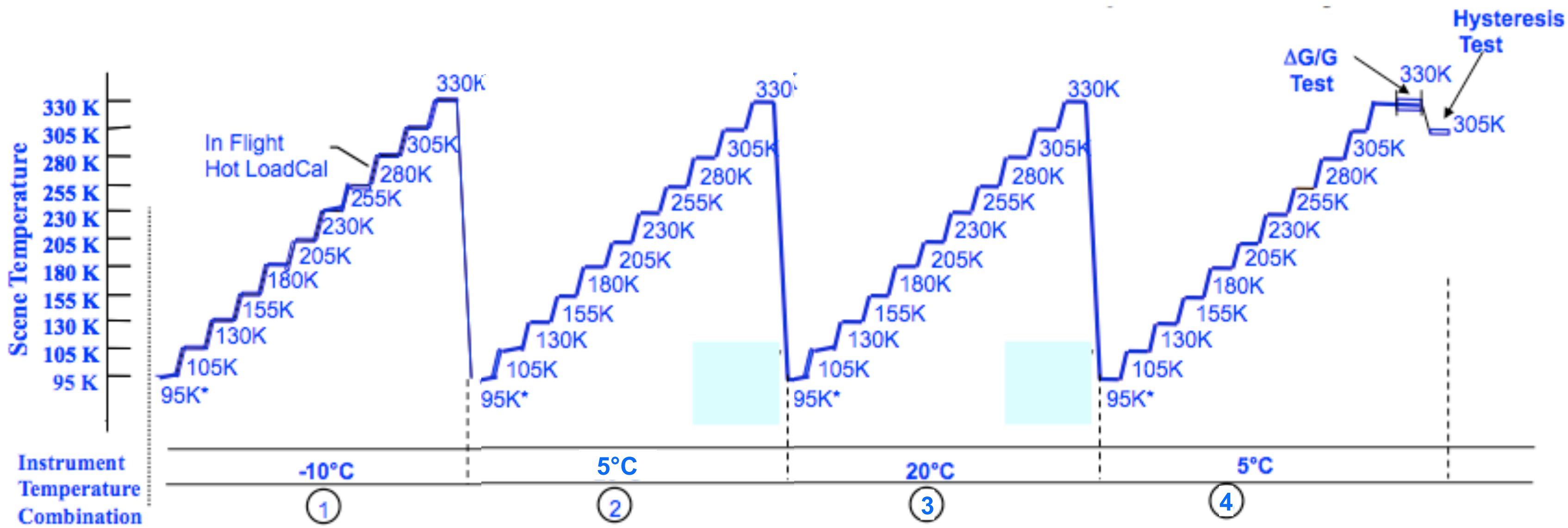
Additional Recommended Testing for FU2

- Antenna pattern testing on compact range
  - More cuts (cross-pol and co-pol) at more beam positions
  - Recommendation: 4 cuts (0, 90, 45, -45) for cross-pol and co-pol at beam positions 1, 24, 48, 72, 96, and SPACE for window channels at 23.8, 31.4, 50.3, 89, 166 GHz. Only the 0 and 90 cross-pol cuts are required for the other channels.
- Integrated Sidelobe (IS) measurement (new test)
  - The antenna range measurements are inadequate to characterize far sidelobes for two reasons: 1) test equipment limitations (lack of sufficient sensitivity and accuracy) and 2) the sensor is not tested under "flight-like" conditions (only antenna subsystem is tested).
  - A high-contrast load using liquid nitrogen and room-temperature absorbers can be constructed and viewed by ATMS in operational mode. Test can be performed in anechoic chamber.
  - NGES will be needed to setup and operate ATMS during the IST. Equipment will be needed to position ATMS over the target.
- Radiometric testing in thermal vacuum
  - Repeatability assessment can be achieved by simply adding an additional stair-step sequence to the testing profile.

Rationale for the Integrated Sidelobe Test

- **Far-sidelobe testing from range measurements is inadequate to predict system performance**
  - **All AMSU sensors have cross-track brightness temperature scan biases and asymmetries with similar pre-launch antenna testing as the NPP ATMS**
- **High-quality antenna pattern measurements are especially needed for ATMS due to footprint resampling in SDR**
- **Proposed IS test will completely characterize the antenna far-sidelobes at the sensor level**
- **No on-orbit spacecraft maneuvers are planned for C1.**

MIT-LL Recommended Thermal Profile for T/V Radiometric Test



• A fourth stair-step section (#2 above) is added to the FU2 configuration
• This allows the repeatability of mission-nominal performance (5°C) to be assessed upon transition from a low-to-high state and high-to-low state
• Characterization of this behavior will lead to a better nonlinear correction and uncertainty estimate (“can we trust the correction on-orbit”)

Graphs were taken from the NGES ATMS PFM Pre-Environmental Review Presentation Apr. ‘05

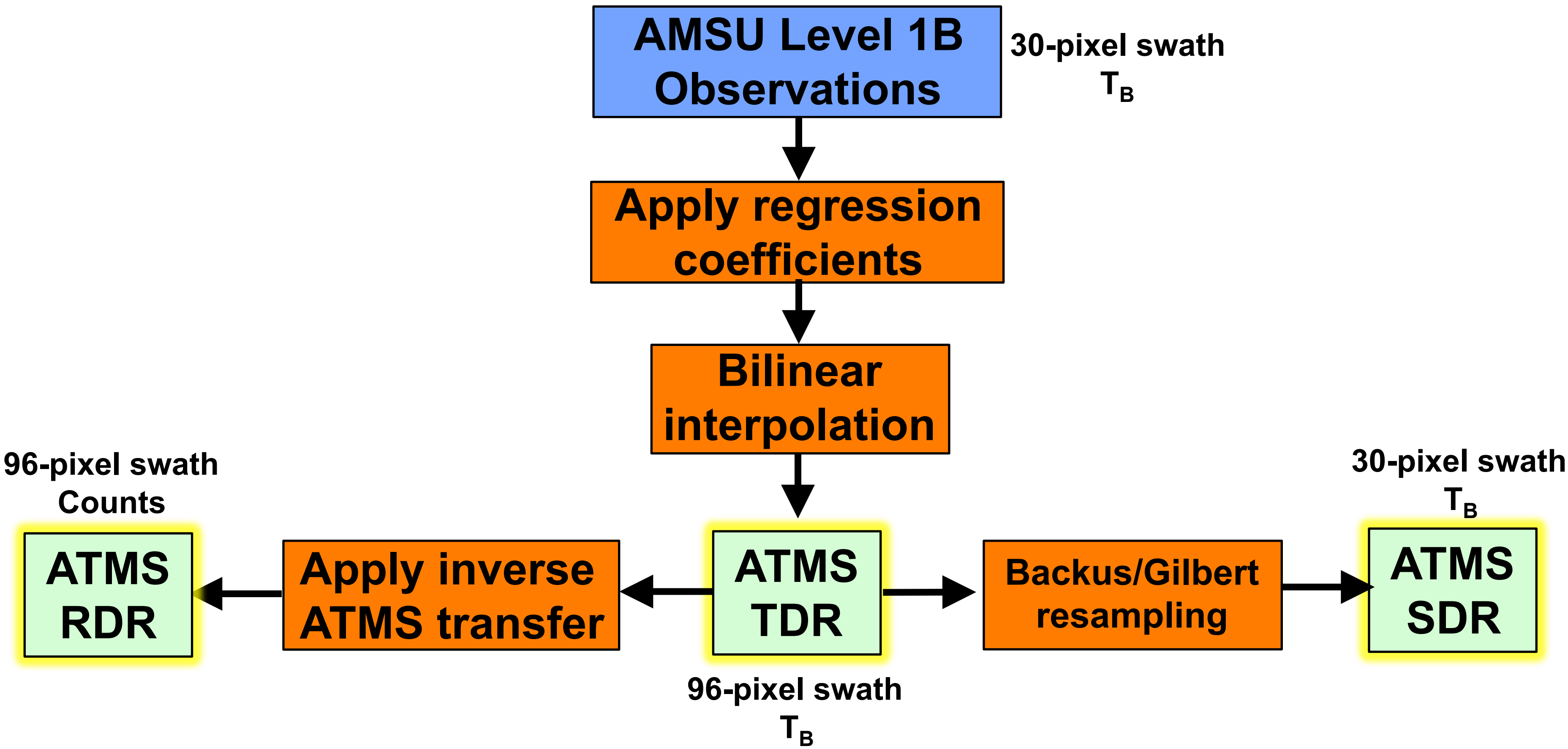
Next Steps

- Work with NGES/NGST to assess cost/schedule impacts
- Continue to refine quantitative estimates of SDR/EDR/CDR impact
- Develop test plan for Integrated Sidelobe Test
- Coordinate with IPO/NGST and NASA Cal/Val efforts

Generation of ATMS Proxy Data

- AMSU-A/B observations can be transformed (spatially and spectrally) to resemble ATMS observations
  - 11 channels are identical
  - 5 channels are identical EXCEPT for polarization
  - 6 channels are new, but can be estimated [with some error]
  - Footprint sizes and spatial sampling are different for frequencies < 89 GHz
  - ATMS measures wider swath angles
  - Orbits altitudes are slightly different

ATMS Proxy Data Generation Flow Chart



Generation of TDR/SDR ATMS proxy data

- Radiative transfer, sensor noise, and surface emissivity/ polarization models are used to simulate global ensembles of AMSU and ATMS data for a variety of viewing conditions (surface type, lat/lon, scan angle, season)

- Regression coefficients are derived for each dataset pairing

- ATMS spatial properties are created using bilinear interpolation

Generation of ATMS RDR Proxy Data

- **Pre-launch radiometric T/V test data is used to derive nominal ATMS transfer functions**
- **These transfer functions are used to transform ATMS TDR proxy data to ATMS RDR proxy data**

ATMS/CrIMSS SDR/EDR Error Modeling

- **There is a need for simple, accurate error models with budgets for accuracy and precision resulting from:**
  - **Scan biases, nonlinearity, calibration biases, NEdT, pointing errors, polarization impurity, many others…**
- **SDR error model is relatively straightforward (linear calibration)**
- **EDR error modeling is much more difficult (highly nonlinear and dependent on scene conditions)**

CrIMSS EDR Error Modeling

- We are developing a high-fidelity EDR error model based on a neural network retrieval using CrIMSS proxy data from IASI/AMSU
  – NN retrieval much easier to use than iterated, model-based retrievals – NN is mathematically well-behaved (continuous and differentiable)
  – Derived error sensitivities likely to be different than NGST retrieval, but this can be calibrated using a few cases

- NN EDR error model will facilitate propagation of error sources, such as those discuss earlier (scan biases, polarization impurity, nonlinearity uncertainty, etc.)

Summary

- **Additional pre-launch ATMS testing (predominantly on FU2, but potentially also on PFM) could better define critical calibration parameters needed in the SDR algorithm, thereby improving SDR absolute accuracy and EDR quality.**
  - **Detailed impacts currently under study**
  - **Dialog with NGES/NGST started**
  - **Test plans under development (IST needs further refinement)**

- **Community ATMS proxy data generator in the works to facilitate performance assessment and error modeling. We are working with Xu Liu to incorporate CrIS; plan to consolidate efforts with Goddard group.**

- **Neural Network SDR/EDR error modeling tools using CrIS/ ATMS proxy data should further improve performance and uncertainty assessments.**